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THE DEVELOPMENT OF SÃO PAULO'S METRO NETWORK AND SOCIO-SPATIAL SEGREGATION

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ABSTRACT

This paper analyzes the spatial distribution of São Paulo's metro network (rail rapid transit) since its creation in 1967 and its relation to urban agglomeration of Metropolitan Region of São Paulo, the biggest metropolis in Brazil. The objective is to understand if the expansion of this network caused significant changes in the urban structure. Using maps, built and planned lines were overlaid to socioeconomic data (population density, employment distribution, average incomes, and other indices), to understand and analyze the chronology of construction. Despite some significant improvements in the rail network, it still reinforces the existing spatial differentiation, the socio-spatial segregation and limits the socioeconomic structure transformation. We can conclude that the limited extension of the metropolitan network, its slow pace of construction, and the decisions of lines priorities has a weak contribution to increasing the population's mobility, mainly low-income ones.

Keywords: Public Transportation, Rail Rapid Transit, Metro, Subway, Transit Network, Metropolitan Region, Urban Planning

RESUMO

Este artigo analisa a distribuição espacial da rede do metrô de São Paulo desde a sua criação em 1967 e sua relação com a ocupação urbana da Região Metropolitana de São Paulo, a maior metrópole do Brasil. O objetivo é entender se a expansão desta rede provocou transformações significativas na estrutura urbana. Por meio de mapas, sobrepusemos as linhas construídas, as redes planejadas e dados socioeconômicos (densidade populacional, distribuição de empregos, rendimentos médios e outros indicadores), para entender a cronologia da construção. Apesar de algumas melhorias significativas na rede ferroviária, ela ainda reforça a diferenciação espacial existente, a segregação socioespacial e limita a transformação da estrutura socioeconômica. Podemos concluir com que a extensão limitada da rede metropolitana, seu ritmo lento de construção e as decisões das linhas prioritárias têm contribuído muito pouco para melhorar a mobilidade da população, principalmente de baixa renda.

Palavras-chave: Transporte Público, Metrô, Transporte de alta capacidade, Rede de Transporte, Região Metropolitana, Planejamento Urbano

1. INTRODUCTION

The metro[1] network can be considered a structural system for urban transit[2], as its high capacity allows it deal with large demands and can increase social productivity significantly. So, its planning should be consistent in order to support the planning and operation of other modes of urban transit.

The metro network of the Metropolitan Region of São Paulo (RMSP) was planned and built between 1967 and 1974. Since then, 101.4 km of the metro network have been built in 6 lines. Despite being the largest metro network in the country, it is insufficient to meet the demands of the São Paulo metropolis.

We will focus on this constant changes and disposal of plans for the metro network, published by the State - São Paulo City Hall (PMSP), Metropolitan Transport Secretariat (STM), São Paulo Metropolitan Company (Metrô) and São Paulo State Government (GESP)[3]. By checking what's planned and published by the State companies, we can see that there are quite adequate plans that have not been carried out. A large part of these planned networks seeks to expand the services to the population as a whole, including suburbs and low income populations.

However, what we found is that the built lines, usually smaller than planned, tend to favor areas of high income and higher employment density. They systematically postpone or give up to reach low-income and high population areas, as well as to stimulate the development of new centers. The lack of operating lines in some areas is not a lack of plans, which sometimes even overlaps, but is a result of subsequent decisions.

This paper begins by presenting the existing metro network in the Metropolitan Region of São Paulo. It'll follow with the socio-economic situation of urban occupation based on data from the Origin-Destination Survey (OD). The last part presents the plans for the metro network since its inception and an overview of planning and achievements, followed by the conclusions.

[1] We chose to use "metro" to the rail rapid transit system instead of common English terms "subway" and "underground" because the mode is defined more by its metropolitan role and high-capacity than its way's urban insertion – which can be by tunnels, elevated or on the ground level. Furthermore, it's the way this system is named in Brazil.

[2] "Transit" here means urban passenger transportation.

[3] The conclusions presented here are the result of previously developed studies, with updates and additions (ISODA, 2013; ISODA & MORI, 2019a; ISODA & MORI 2019b).

2. SÃO PAULO METRO NETWORK

The Metropolitan Region of São Paulo is an urban agglomeration made up of 39 municipalities. It has an estimated population of 22 million inhabitants, which places it among the 5 largest metropolises in the world. Its metro network has 5 lines, plus 2 new lines under construction, which makes it the largest and most complex metro system in Brazil (Figure 1 and Figure 3). But it's relatively small to its population, comparing with other metropolises around the world. (Figure 2).

The RMSP rail passenger transport network is formed by seven commuter rail lines, operated by Companhia Paulista de Trens Metropolitanos (CPTM) and by five metro lines and one monorail, operated by Companhia do Metropolitano de São Paulo (Metrô). They are constituted as slightly different modes of transport, which present differences mainly in their urban insertion (due to the origins of each line and its historical development), but which from a technological point of view have many similarities. We'll focus on the Metrô network.

Figure 1 – Current São Paulo's metro network (operating and under construction)

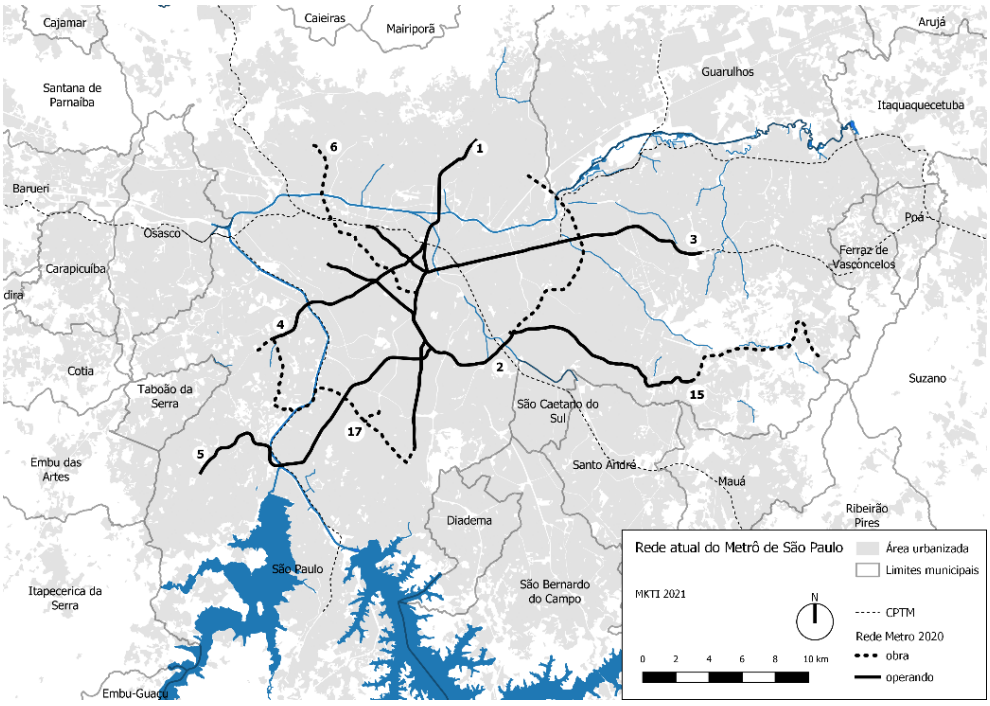
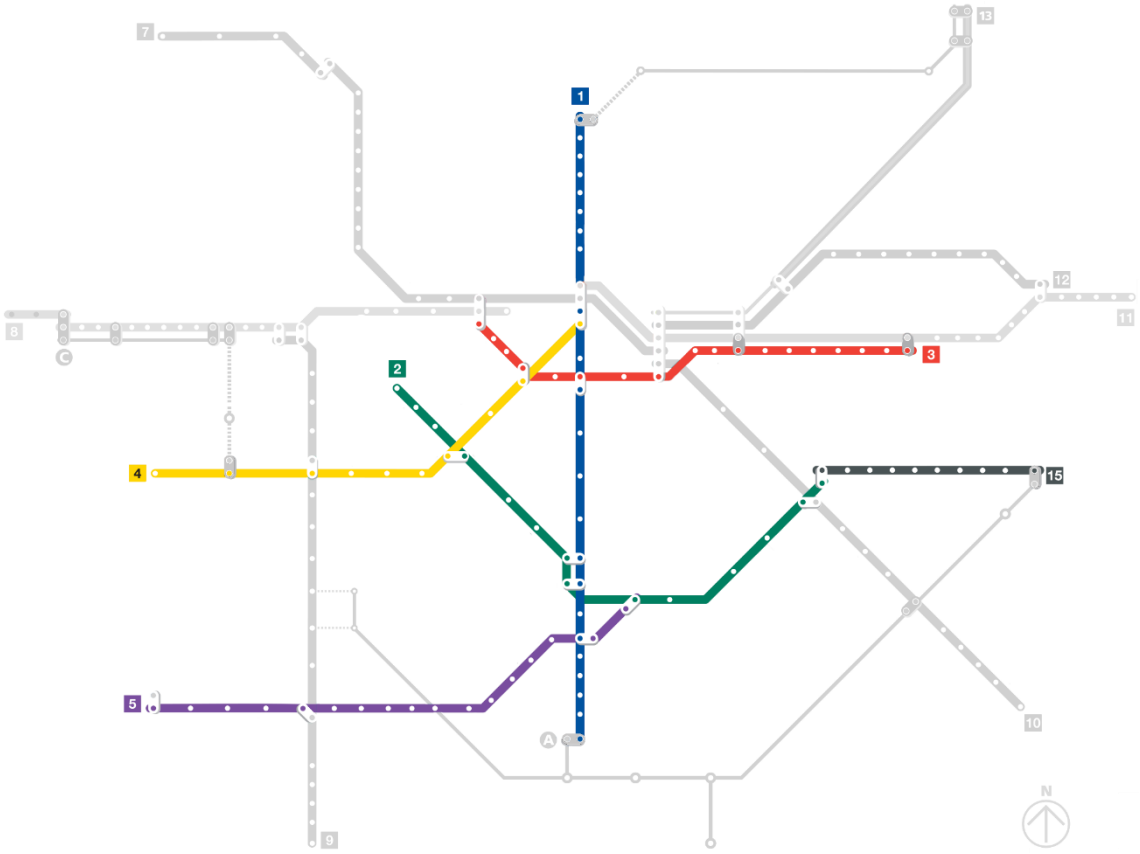


Figure 2 – Metro network per inhabitant
(Source: Metrô SP; CPTM; IBGE; Ovenden, 2009; Sort, 2005)

City	L (km)	Pop (mi)	L/Pop
London	438.73	11.6	37.8
Paris	211.30	10.7	19.7
Berlin	151.70	4.3	35.3
Milão	74.60	4.3	17.3
New York	368.05	15.8	23.3
Mexico City	177.10	18.3	9.7
Buenos Aires	48.94	12.9	3.8
Santiago	94.20	6.1	15.4
São Paulo (Metrô)	101.40	22.0	4.6
São Paulo (Metrô + CPTM)	371.00	22.0	16.9

The metro network currently has 101.4 km of lines exclusively for passengers, which despite a reasonable expansion in recent years, still has a timid urban coverage, focusing primarily on the expanded center and the areas with the highest concentration of income and jobs in the metropolis. The network consists of six lines in operation, each identified by a number and a color[4]. The lines were inaugurated in the following order: Line 1-Blue, Line 3-Green, Line 2 - Green, Line 5-Lilac, Line 4-Yellow, and Line 15-Silver, as shown in the map and graph below (Figure 4 and Figure 5). Lines 2, 4 and 15 have branches currently under construction. In addition to these, there are two more under construction, Line 6-Orange, and Line 17-Gold (Figure 1). The numbering of lines is confusing for some reasons: because it encompasses the 7 lines of CPTM network; and because planned construction priorities were not followed.

Figure 3 – Official São Paulo's metro network in 2021 (adapted from Metrô Company)



The RMSP metro network had a very fickle development and a slow pace of construction (average of 1.91 km/year), with long periods of stagnation (Figure 4). In recent decades, there has been a significant leap in contracted works and oppenings. Most of these works are currently facing great delay problems, with contract terminations and changes of construction consortia.

[4] These names were adopted in the 1990s and are quite confusing, as we going to see. Older documents will have different names.

Figure 4 – Expansion of the metro network over time (operating and under construction)

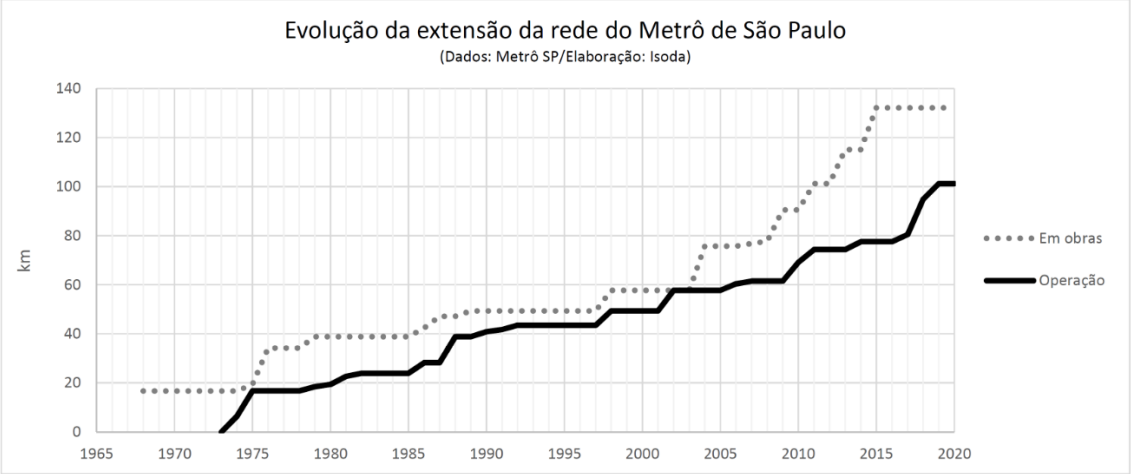
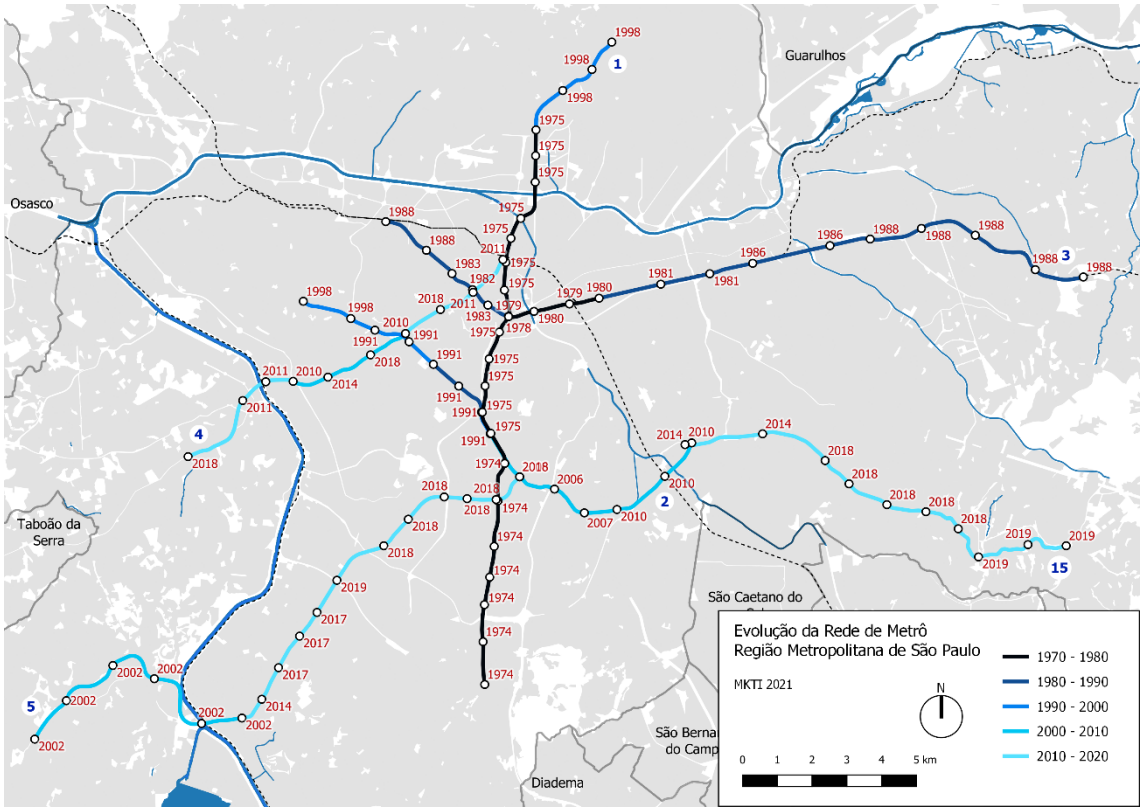


Figure 5 - Evolution of the extension of the São Paulo metro network (opening year)

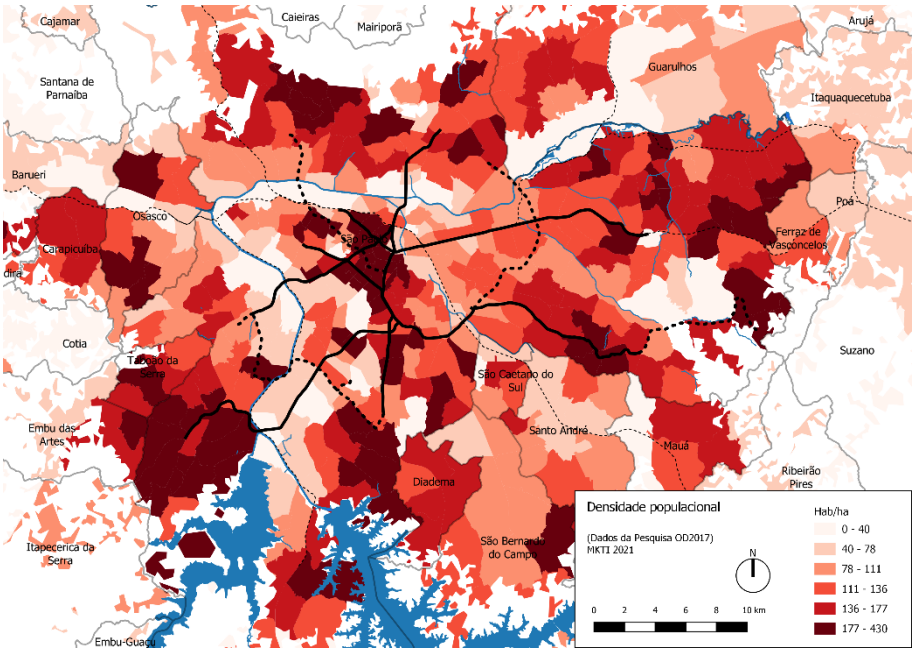


3. SÃO PAULO METROPOLITAN REGION

In this section we'll see the insertion of the metro network over the urban structure. The maps were generated with socioeconomic data from the Origin-Destination Survey (mainly 2017), carried out by the São Paulo Metrô Company[5].

The population density is well distributed throughout the entire urbanized area, with high densities (around 200 inhab/ha) both in the center and on the outskirts (Figure 6). The lower densities correspond to areas of more difficult occupation, such as the floodplains of large rivers, regions with a high concentration of industries and large equipment (airports, parks, etc.). The maps show that many densely populated areas are not served by the metro network.

Figure 6 - São Paulo metro network and population density
(inhabitants per hectare, OD Survey 2017)



As pointed out by several authors (VILLAÇA, 2001; DEÁK, 2002), the RMSP can be characterized by a concentration of high-income people and activities in the central region and the southwest sector, as can be seen in the maps below. Lines 2, 4, and 5 cross the high and very high-income regions (Figure 7). The largest volume of recent investment in the metro network was made in more valued regions, which also concentrate a large part of the jobs (Figure 8).

There are some exceptions. But the branches that reach peripheral regions tend to be technologically downgraded. The north branch o Line 1 and the southwest branch of Line 5 were built in elevated ways; the east branch of Line 3 is on the ground level; and Line 15 has a different system, the monorail (with less carrying capacity, does not reach the center and depends on a single connection to the network).

[5] The maps were made using the free open-source software QGIS 3.4.6.

Figure 7 - São Paulo metro network and and average family income (monthly minimum wages, OD Survey 2017)

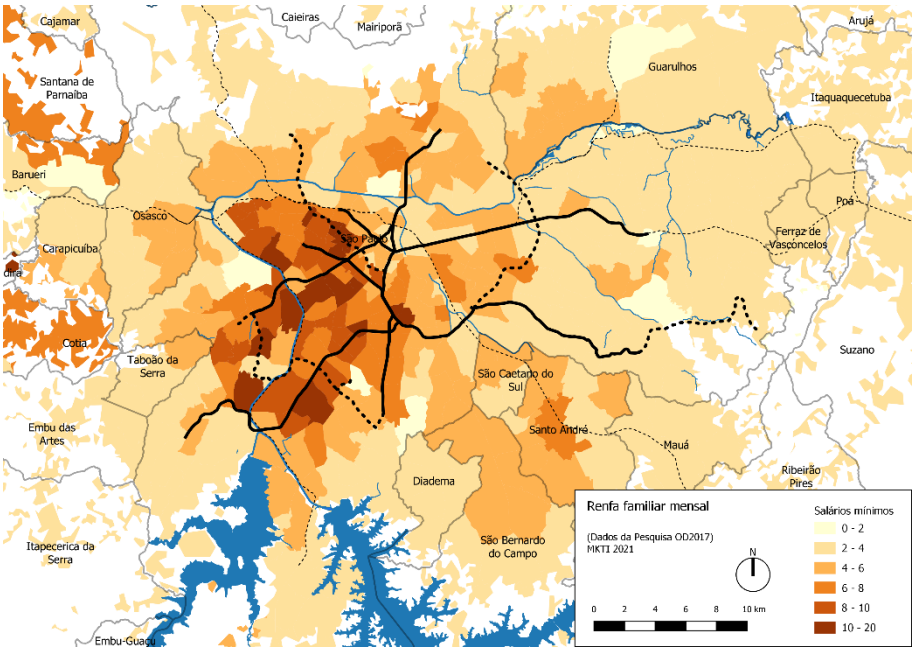
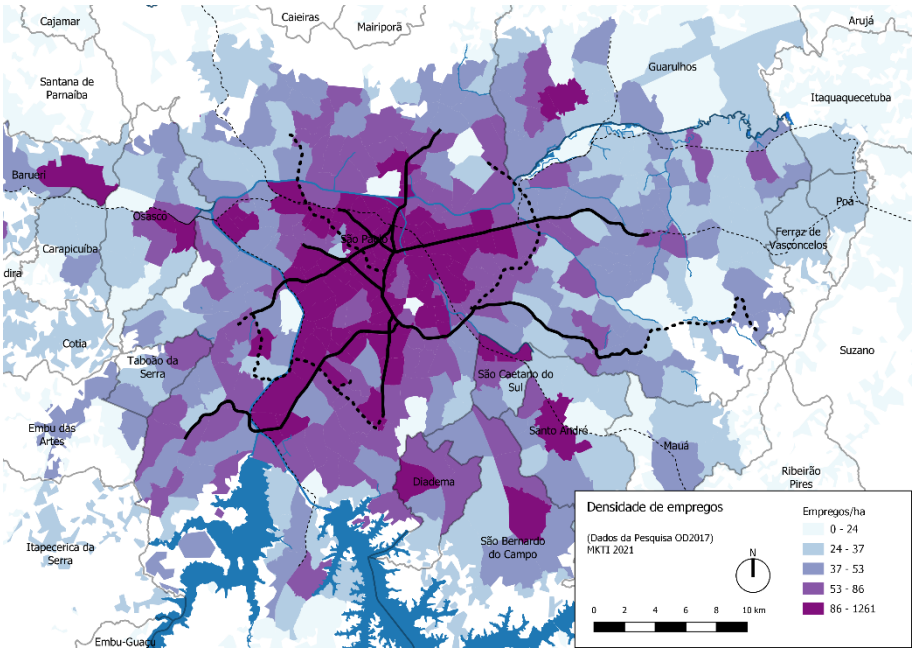
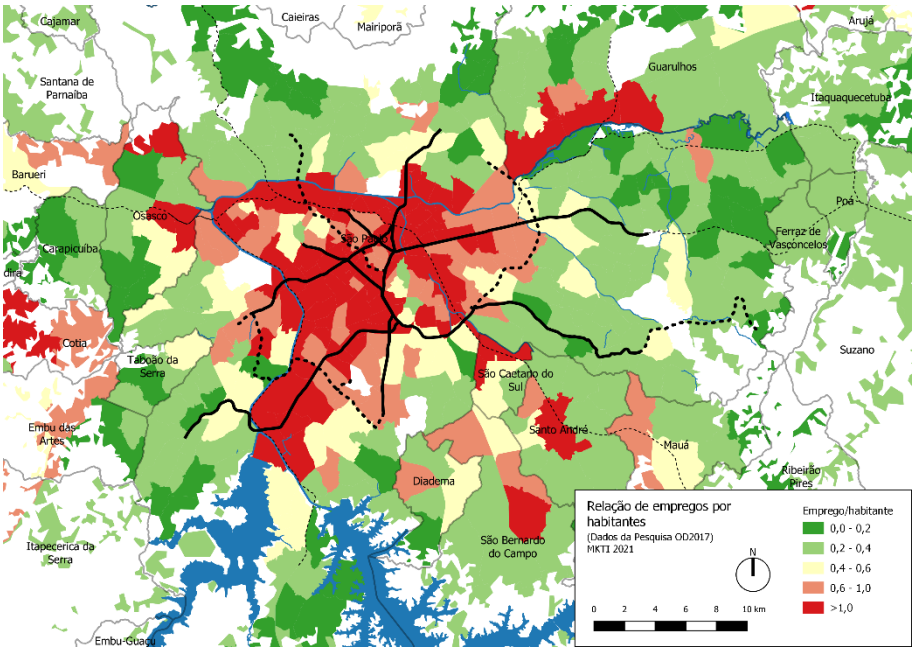


Figure 8 - São Paulo metro network and job density (jobs per hectare, OD Survey 2017)



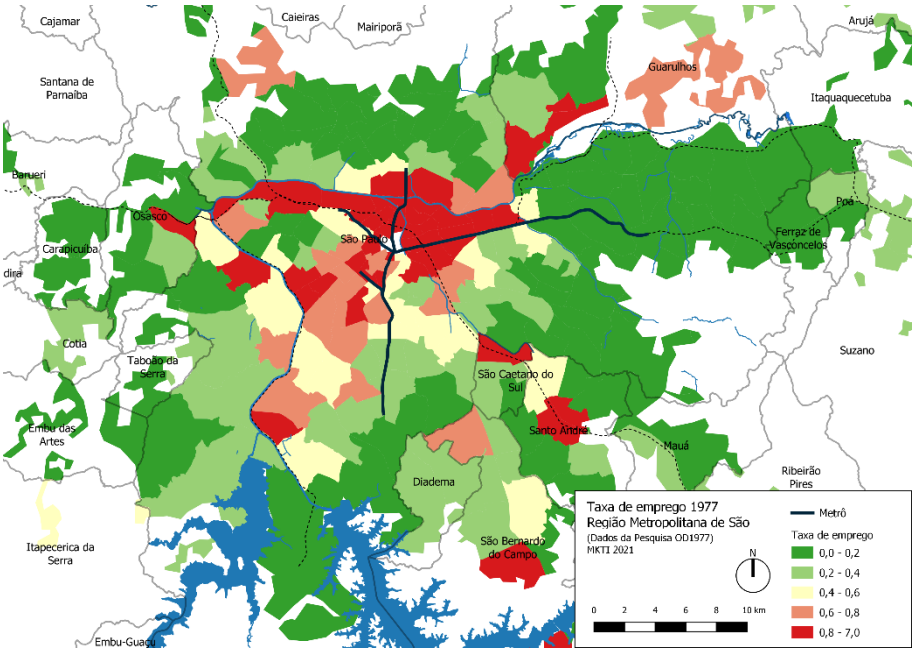
By dividing jobs by population, we can estimate where the greatest demand for travel is (Figure 9). The areas with the lowest number of jobs per inhabitant are travel-generating regions (in green), while the areas with the highest amount are travel-attractors (in red). If, on the one hand, the metro network provides access to many jobs, on the other hand, it does not reach high-density residential neighborhoods.

Figure 9 – São Paulo metro network and relationship between jobs and population (OD Survey 2017)



When comparing the current data with the urban structure in the first years of the metro network's operation, we can see that despite an urban expansion and an increase in activities, the concentration of jobs was similar (Figure 10). The expansion of jobs per capita in the southwest direction took place throughout the 1990s and 2000, when there was large government investment in road infrastructure and urban development, before the construction of lines 4 and 5.

Figure 10 - São Paulo metro network and relationship between jobs and population (OD Survey 1977, metro network 1980)



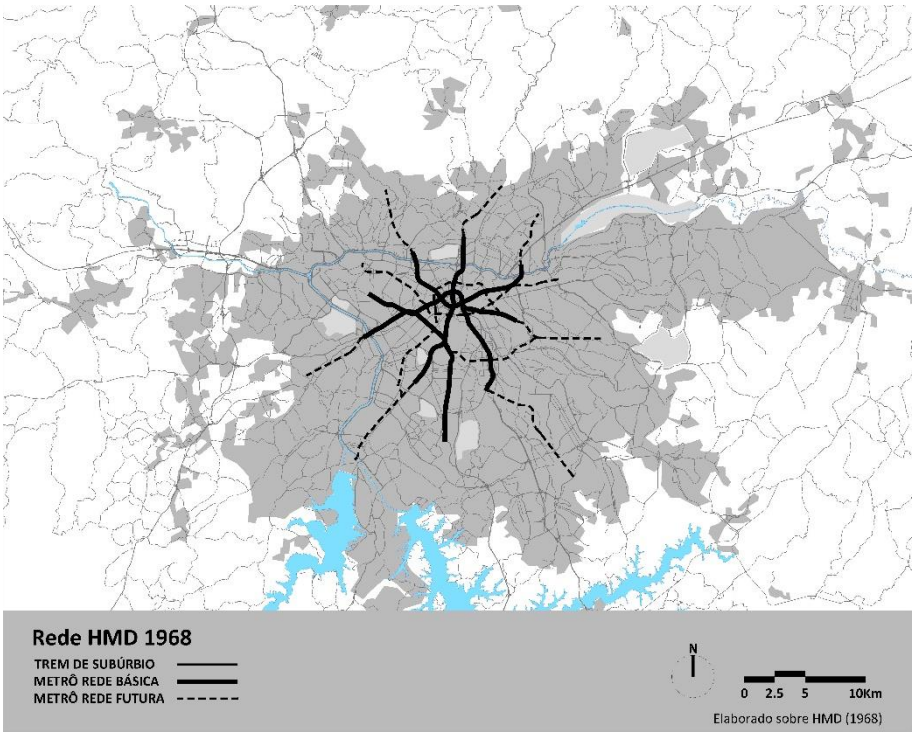
4. METRO NETWORK PLANNING

Next, we will briefly recapitulate the main plans for the São Paulo Metrô network over its 50 years of existence, seeking to understand the different network organizations, evaluation methods, and the built results.

In 1968, the Municipality of São Paulo created the São Paulo Metropolitan Company and published the study "São Paulo Metro - Integrated System of Collective Rapid Transport of the City of São Paulo", carried out by the HMD consortium (Hochtief, Montreal and Deconsult, 1968). From this study, Line 1-Blue (north-south) was developed and built[6].

The Basic Network proposed by the HMD (Figure 11) has 66.2 km in 4 lines and 2 branches, which are approximately equivalent to the current lines 1-Blue (with a southwest branch towards Moema, similar to the guideline of the current Line 5-Lilac), 3-Red (in a northeast-northwest arc), 4-Yellow (in a southeast-southwest arc and with a Vila Bertioga branch to east) and 2-Green. The target year for this network was 1986 and the projected population was 12.1 million inhabitants.

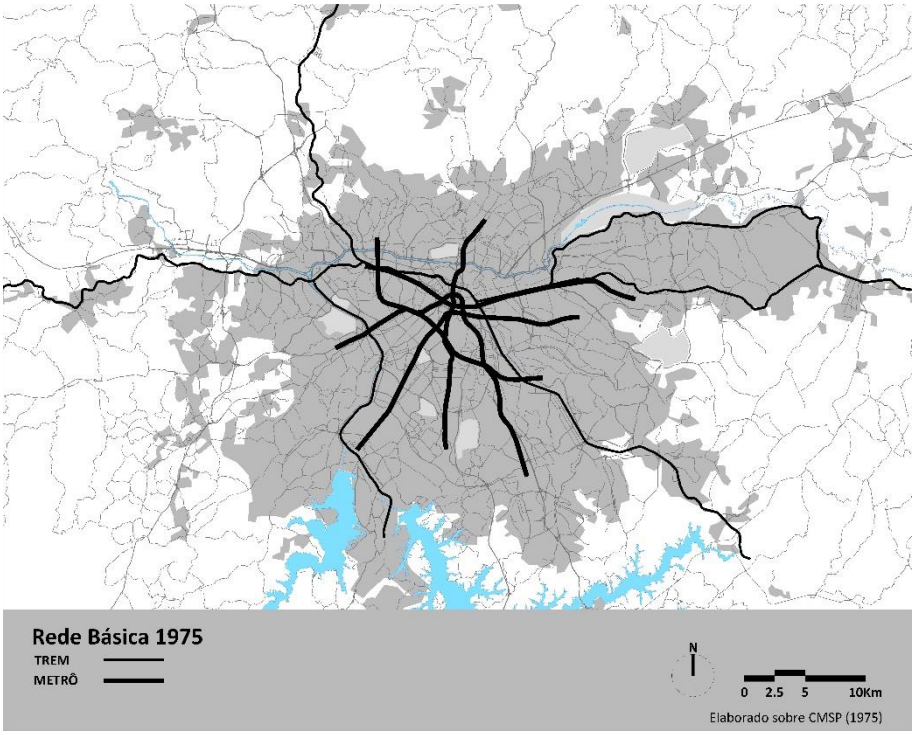
Figure 11 - HMD Basic Network (1968)



In 1975 the Basic Network was published, with 128 km length and composed of 5 lines (Figure 12). It has a balanced organization, with a good number of connections and a great spatial coverage (compared to plans at the time), reaching peripheral regions that have not yet been served. This network resulted in the guideline for the implementation of the second line, to the east-west, current Line 3-Red, following the existing railway line.

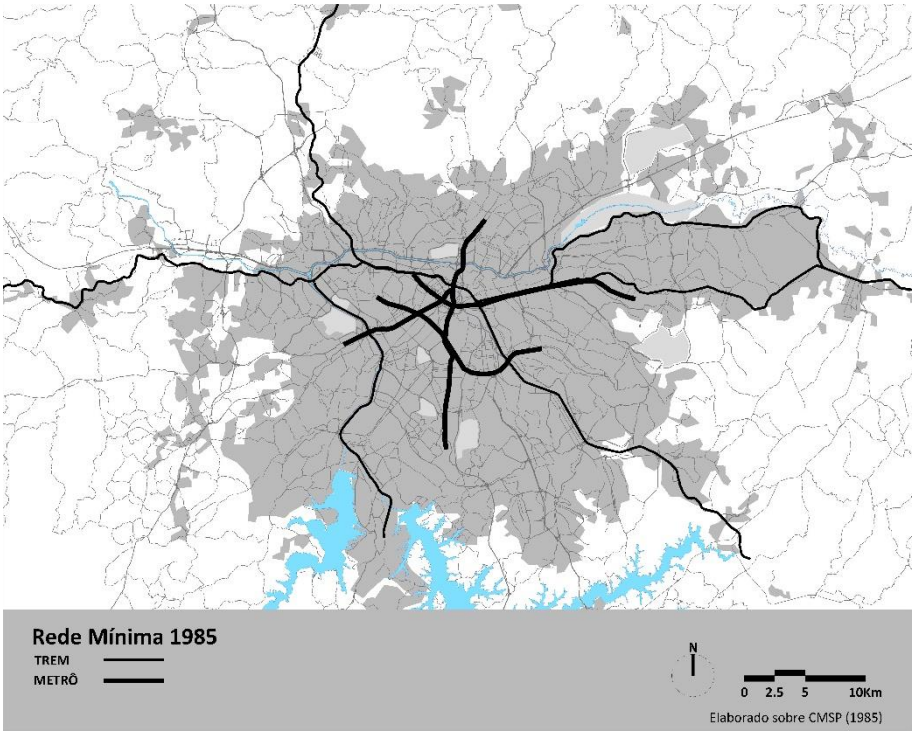
[6] Before this, there had been 12 other studies for metro systems for São Paulo, none of them carried out, with the first in 1927 proposed by the Canadian company Light, which operated the trams in the city.

Figure 12 – Basic Network (1975)



The Minimum Network, planned in 1985 (Figure 13), accepts the scarcity of resources at the time by reducing the network to just four lines, all pf them shorter than previous versions, with 67.5 km. Amid an economic recession and with the reduction of investments, the plans became timider, with the simplification of lines and reduction of total lenght and spatial coverage.

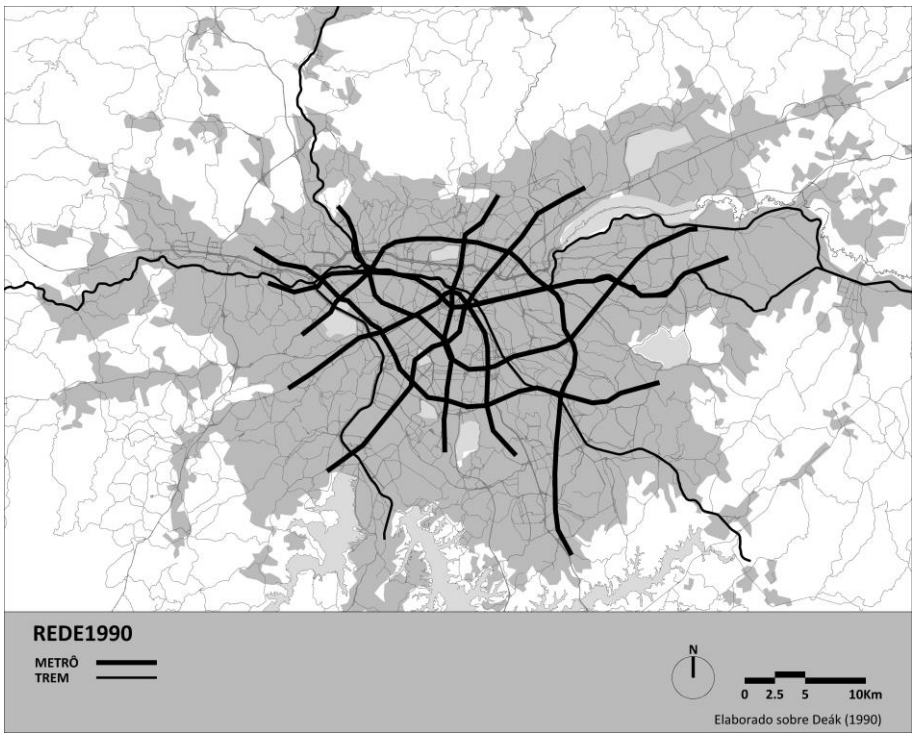
Figure 13 - Minimum Network (1985)



This network defined the route of Line 2-Green (with the western section inaugurated between 1991-1998, but the east section only in 2008-2010), and Line 4-Yellow (opened in 2010 and still under construction).

The end of the 1980s is marked by a drastic reduction in the metro construction. Good studies were carried out in the period by the Metro Company, but not officially published. We highlight here the network from 1990 and with the target year of 2000, published in an academic article (Deák, 1999) after being discarded. The network is 125 km long and seven lines, has a great spatial coverage in a network model that prioritizes connections (Figure 14), which contrasts with the Minimum Network presented above.

Figure 14 – Discarded Network (1990)

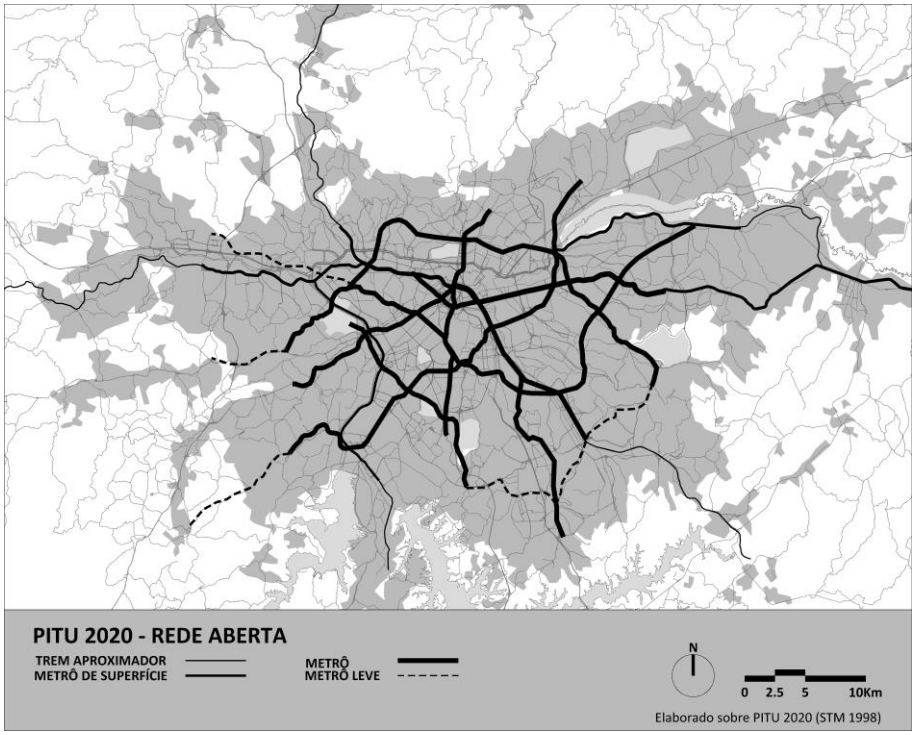


By the end of the 1990s, there was a resumption of metropolitan transport planning, which reflected in a greater volume of proposals. But the amount of plans does not lead to more built network. The intervals between publications were close and the construction pace was so slow theat the plans had almost no effect.

The plans' overlaps, justified as “updates” or “revisions”, did not the correspond to what’s presented. The plans often replace the premises, objectives, working methods, analysis tools, guidelines and propositions of the preceding ones.

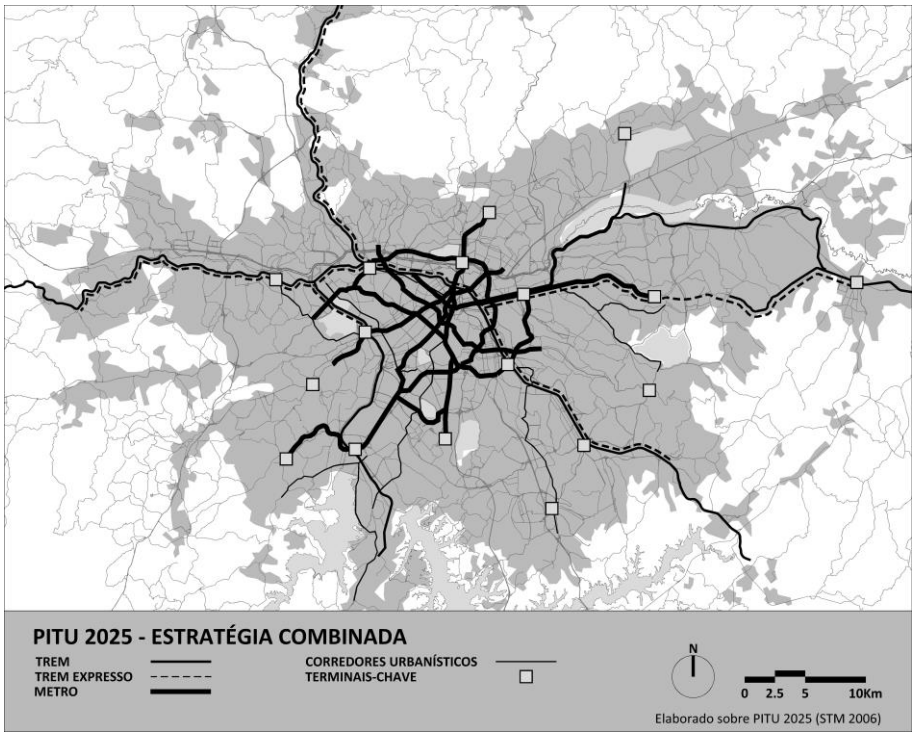
The Integrated Urban Transport Plan for 2020 (Pitu 2020) was published in 1999. It presents a series of proposals, evaluated by a set of indices in three socioeconomic scenarios – full development, moderate growth, and economic stagnation – using mathematical modeling (*Start* model). Three distinct rail network alternatives were presented and the best-evaluated proposal was the Open Network, the most comprehensive of the three, with 173 km in length (Figure 15).

Figure 15 - Pitu 2020 Open Network (1999)



The Integrated Urban Transport Plan with the target year of 2025 (Pitu 2025) was published in 2006, reportedly as a revision and update of Pitu 2020. But this plan uses another mathematical model (*Tranus*) and a new set of indices (similar to its precedent, but simpler). The three metro networks evaluated in this study were similar among them (dense and central), none of them close to the Open Network. The result was a technical tie, with the arbitrary selection of the "preferred" network, called Combined Strategy (Figure 16).

Figure 16 - Pitu 2025 Combined Strategy/Esential Network (2006)

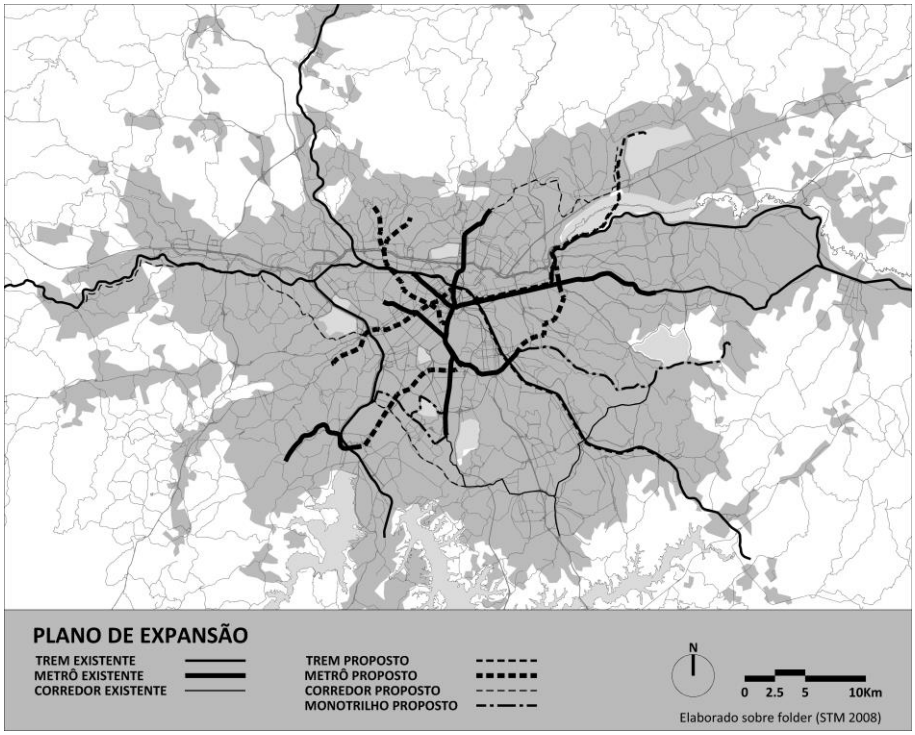


This network has already been published in a previous study by Metrô Company in the same year, called "Essential Network: Priority Sections". – using other methods, another mathematical model (*EMME-2*), and a much smaller set of indicators.

The Expansion Plan, later called Expansão SP, was in effect from 2007 to 2011. Despite being called an "integrated metropolitan plan", it was actually only a government advertising program, a set of investment proposals that do not necessarily relate. It was published through several small booklets and folders, its proposals are in short term and underwent constant changes. There's not an actual network (Figure 17 shows one of these moments), just as there is no evaluation method explained.

It is during this period that monorail system lines began to be announced. In a few years, it went from an unknown technology to a *panacea* for the urban transit. At the time, six monorail lines were announced. Currently there's one monorail line in operation (15-Silver) and one under construction (17-Gold, planned for the 2014 World Cup).

Figure 17 – Expansion Plan (2008)



In 2013, the "Update of the Metropolitan Network of High and Medium Transport Capacity in the RMSP" was published, which presents a structural network for the year 2030 (Figure 18). With 261 km of the metro network and a significant expansion of the CPTM network (which in previous plans was always timid), this network partially returns to a more metropolitan coverage (present in the 1990 and Pitu 2020 networks).

It is the current reference network, despite it has already undergone some changes. It has a remarkable quality, with well-distributed lines and a large number of connections. However, the last few years were marked by a national economic recession, which led to a drastic reduction in investments. Thus, despite the development of functional studies and projects, new construction has not been contracted since 2015 (Figure 4).

Figure 18 - 2030 Network (2013)

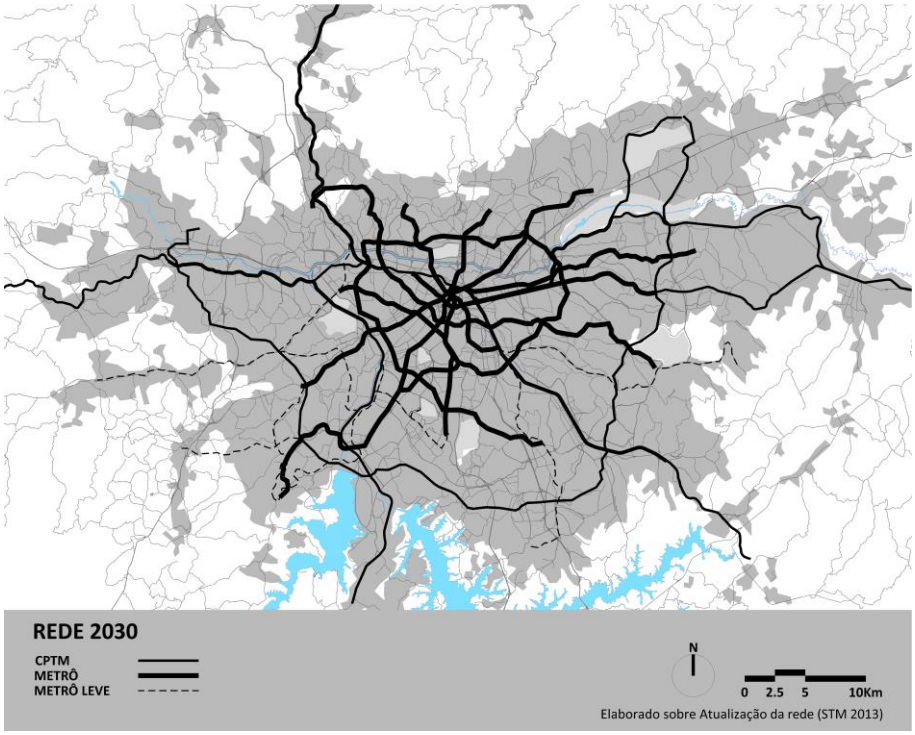


Figure 19 – Metro network plans

Network	L (km)	Estimated Pop (mi)	L/Pop
HMD Basic Network (1968)	66	12.1	5.5
Basic Network (1975)	128	12.1	10.6
Minimun Network (1985)	67	12.1	5.6
Discarded Network (1990)	258	23.0	11.2
Pitu 2020 Open Network (1999)	237	22.4	10.6
Pitu 2025 Combined Strategy (2006)	163	22.2	7.3
Expansion Plan (2008)	-	20.0	-
2030 Network (2013)	252	22.9	11.0
Current São Paulo metro (2021)	101	22.0	4.6

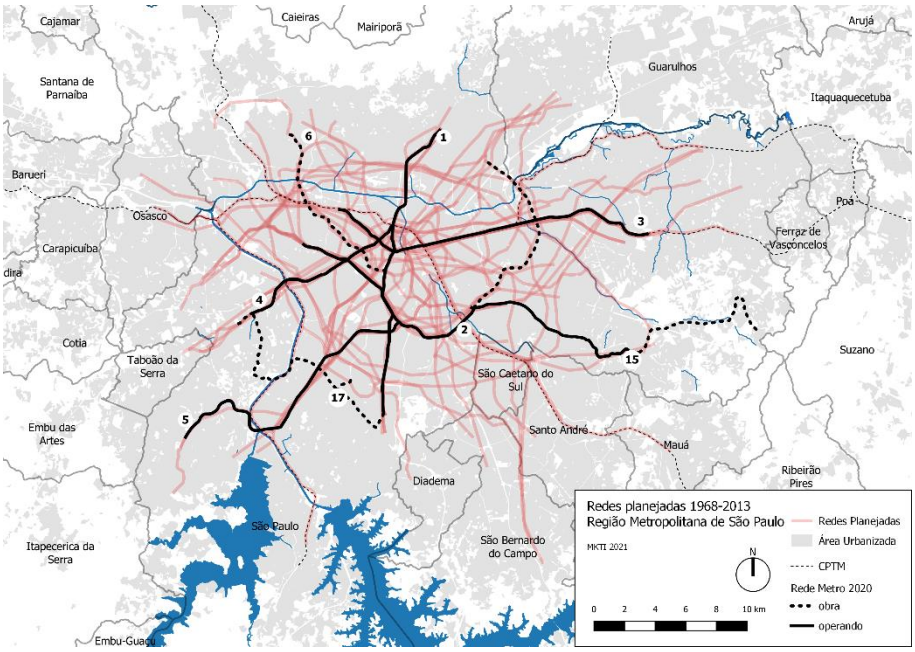
5. CONCLUSION

It became clear that de São Paulo metro network plans went through periods of broader coverage and periods of restrictions. But in a general way, the goals were not met, the guidelines for the lines are changed several times and, when they are built, they are timider than in the studies. Most future networks seek to expand service to all the population, but the built lines tend to favor areas of high income and greater density of jobs (Figure 20). They they systematically postpone or give up reaching densely populated low-income areas or to stimulate the development of new centers.

Despite some periods of increased metro planning activity, the existence of good plans did not make concrete achievements more coherent. In the last two decades there has been an effort to resume metropolitan transit planning in a broader sense. However, the plans published in this period had little influence on the lines implemented. What was opened in this period was already planned before 1990, except for the monorail line.

The analysis of the evaluation methods makes it clear that many major decisions were taken beforehand the elaboration of the plans. Unlike what is declared, there is no continuity of the plans at each review. The changes in the evaluation methods – mathematical models, sets of indices, premises –results in a restart of the planning process, which result in completely different metro network proposals. This constant changes disorient the planning of other spatial interventions, whether urban development guidelines, other transport systems or even the metro system itself.

Figure 20 – Planned Networks (1968-2013) and current metro network



Furthermore, the expansion of the network was negligible given the dimension of the metropolitan demands identified by the plans (Figue 19). There were insufficient achievements to bring significant improvements to metropolitan transport and socioeconomic development. What was built still favors the regions with the highest income and concentration of jobs, which are more valued, and neglects the lower income areas, even where there is a high population density.

The limited extension of the metropolitan network, its slow pace of construction, and the spatial priority decisions have contributed very little to improving the mobility of the population, especially the low-income ones. The conclusion is that the metro network still reinforces the existing spatial differentiation, maintains socio-spatial segregation and limits the transformation of the socioeconomic structure.

The São Paulo metro network effectively built is almost the minimum to avoid the complete stagnation of social production, without an increase in its capacity, even though the demand is constantly rising. It does not seek to transform the present situation and does not use its potential to enhance the development of activities in the urban space or to promote social changes.

Acknowledgments

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